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PERFORMANCE EVALUATION OF HYBRID ARQ SCHEMES OF 3GPP LTE OFDMA SYSTEM

Outline of Presentation

- 3GPP LTE Targets
- System and Channel Model
- Diversity Techniques
  - Subcarrier Rearrangement
  - Constellation Rearrangement
- Performance comparison of enhanced Hybrid ARQ Schemes
- Conclusion

3GPP LTE targets

Develop a framework for the evolution of the 3GPP radio-access technology towards a **high-data-rate, low-latency and packet-optimized** radio-access technology:

- Support of packet switched domain only (including VoIP).
- Significantly increased peak data rate: 100 Mbps (downlink) and 50 Mbps (uplink)
- 2 or 4 times capacity over Release 6 reference scenarios with HSDPA or HSUPA.
- Scalable bandwidth up to 20 MHz (lowest possible BW: 1.25 MHz).
- Radio Network user plane latency below 10 ms (RTT) with 5 MHz or higher spectrum allocation.
- Reduced complexity (of terminals)
- Need for inter-working with WCDMA and GSM based networks.

Parameters for LTE OFDMA Downlink Transmission

Transmission BW		1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		0.5 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 × 3.84 MHz)	3.84 MHz	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††		76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)		7/6					
CP length (μs/samples)	Short	(4.69/9) × 6, (5.21/10) × 1*	(4.69/18) × 6, (5.21/20) × 1	(4.69/36) × 6, (5.21/40) × 1	(4.69/72) × 6, (5.21/80) × 1	(4.69/108) × 6, (5.21/120) × 1	(4.69/144) × 6, (5.21/160) ×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

- Sub-carrier spacing is constant regardless of the transmission bandwidth
- Transmission bandwidth is varied by varying number of OFDM sub carriers to allow for operation in differently size spectrum
- Sub frame duration correspond to the minimum downlink TTI

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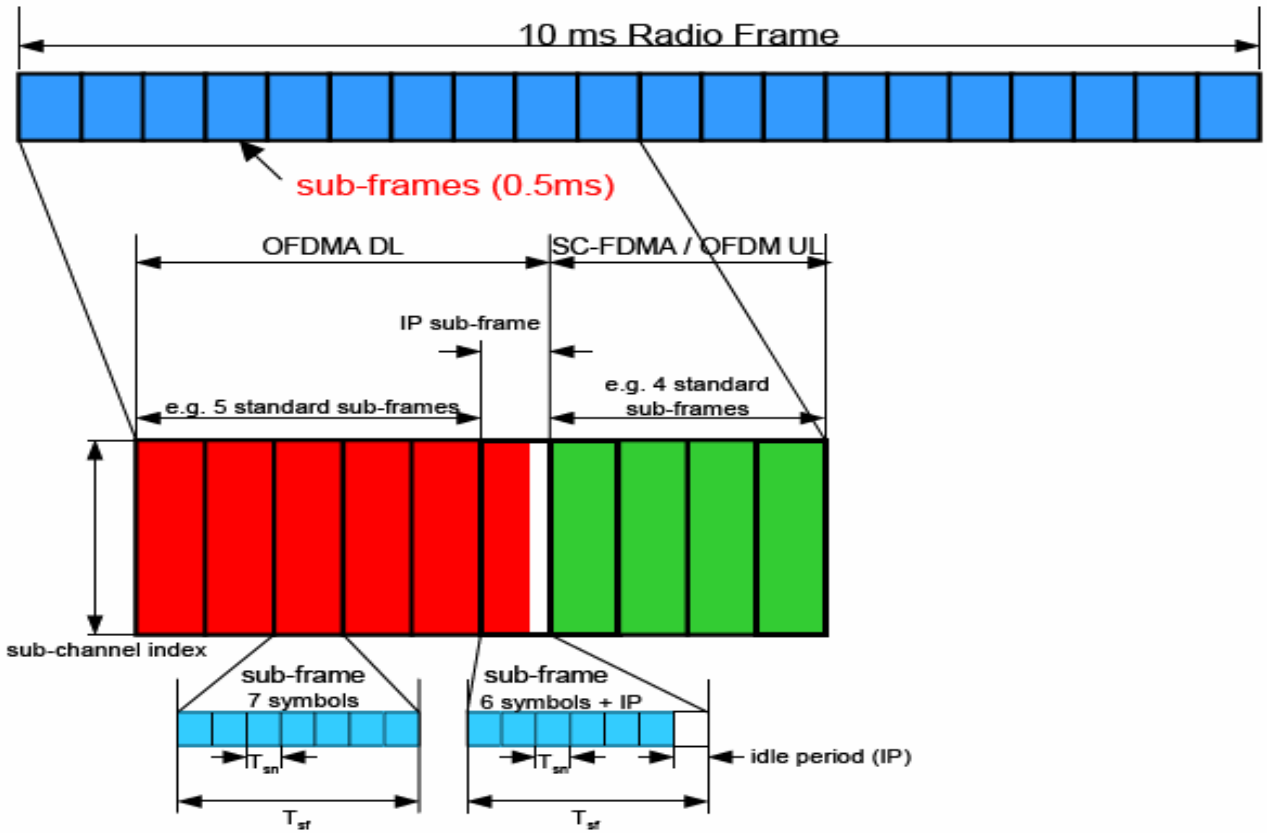
Generic Frame Structure



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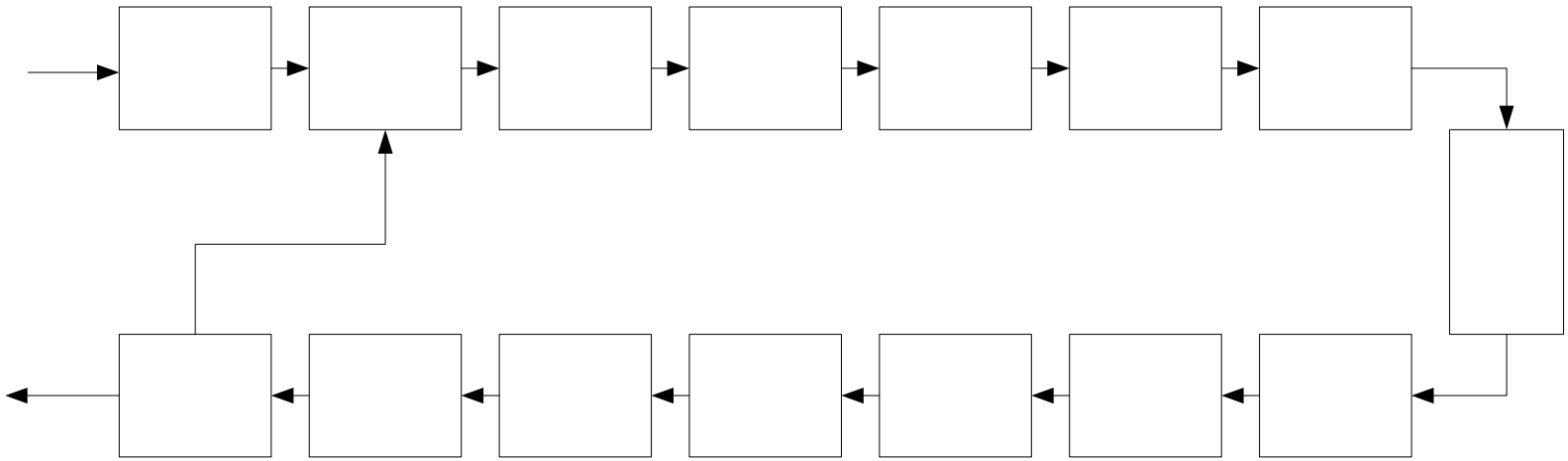
Proposed OFDMA System Model



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Channel Model

- 3GPP Spatial Channel Model Extended
- SISO/MIMO radio channel models that are commonly accepted and used
- Three environments are specified
  - Suburban Macrocell (aprrox. 3km distance BS to BS)
  - Urban Macrocell (approx. 3km distance BS to BS)
  - Urban Microcell (approx. 1km distance BS to BS)
- 6 paths tap delay line model

Tapped Delay- Line Parameters

Scenario		Suburban -Macro		Urban Macro		Urban Micro	
Power - Delay Parameters (relative)	1	0	0	0	0	0	0
	2	-2.6682	0.1408	-2.2204	0.3600	-1.2661	0.2840
	3	-6.2147	0.0626	-1.7184	0.2527	-2.7201	0.2047
	4	-10.4132	0.4015	-5.1896	1.0387	-4.2973	0.6623
	5	-16.4735	1.3830	-9.0516	2.7300	-6.0140	0.8066
	6	-22.1898	2.8280	-12.5013	4.5977	-8.4306	0.9227
Resulting Total DS (us)		0.231		0.841		0.294	

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System Simulation parameters

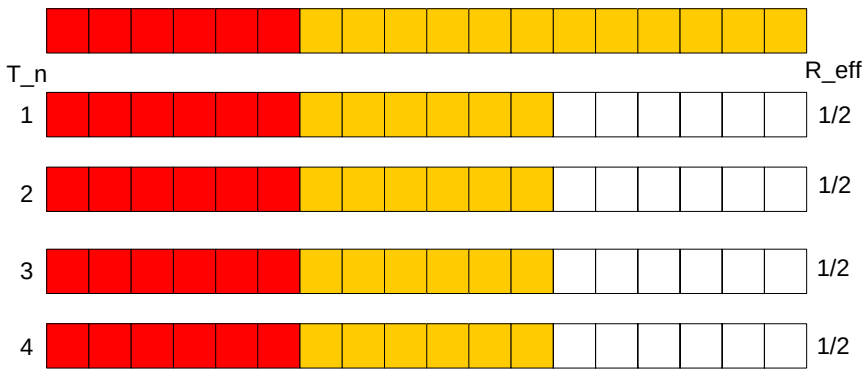
- Several HARQ techniques are considered
  - Simple ARQ (Type I)
  - Chase Combining (Type I with CC)
  - Full IR (Type II)
  - Partial IR (Type III)
- Focused at static environment (channels remain invariant in the retransmissions)
- Retransmission is limited to 4
- 54 bytes packet size

Rate Compatible Punctured Turbo (RCPT)

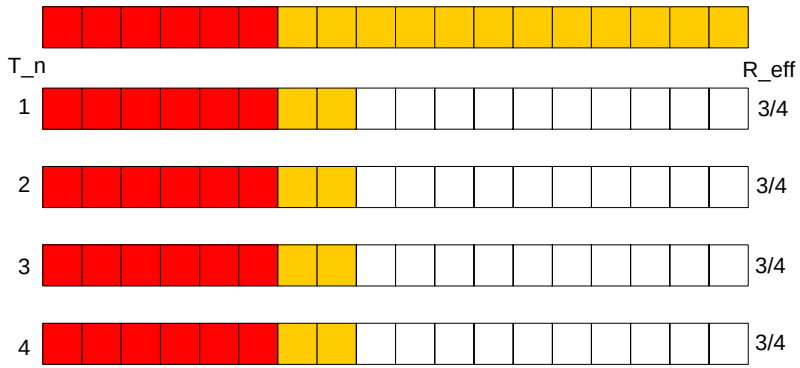
- Turbo code introduced in 1993
- Concept of RCPT codes introduced in 1995 first used in ARQ protocol in 1997 in literature
- Enable Incremental Redundancy techniques
- Rate 1/3 mother turbo code
- A puncturing period of 6 is used in the simulation to form code rates of 3/4 and 1/2.

Puncturing Pattern

Chase Combining



½ Rate



¾ Rate

- **Soft bit values from different retransmission(s) are added to obtain the combined value of soft bits**
- **Obtain soft combining and diversity gain**

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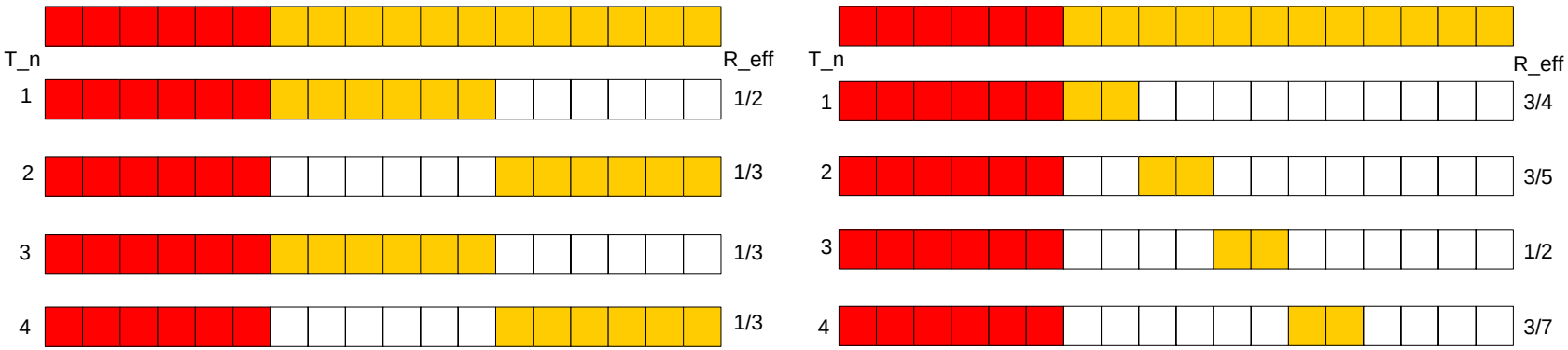
Puncturing Pattern

Partial Incremental Redundancy



½ Rate

¾ Rate

- **Soft bit values from different retransmission(s) are added to obtain the combined value of soft bits**
- **Obtain soft combining and diversity gain**

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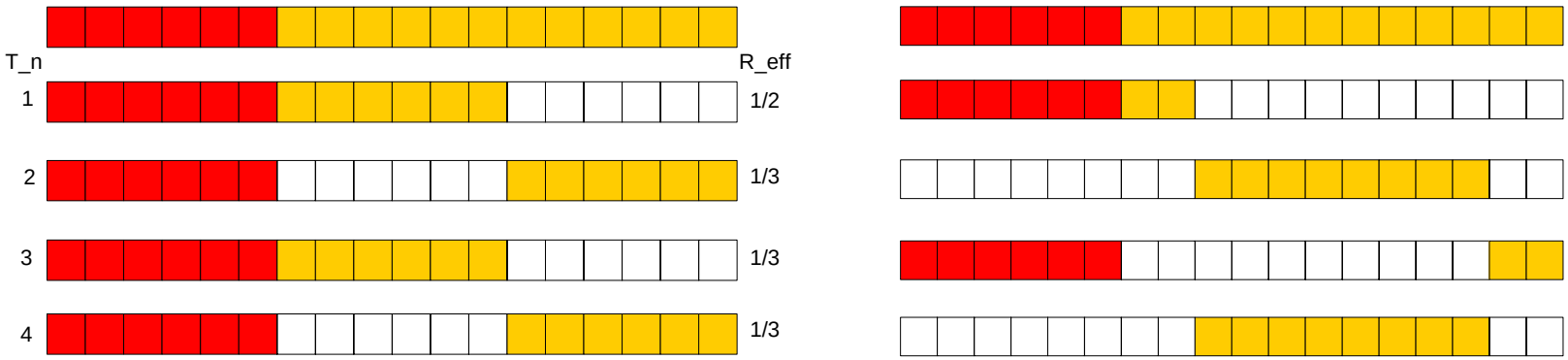
Puncturing Pattern

Full Incremental Redundancy



½ Rate

¾ Rate

- **Soft bit values from different retransmission(s) are added to obtain the combined value of soft bits**
- **Obtain soft combining and diversity gain**

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Modulation and Coding Schemes Used in the simulation

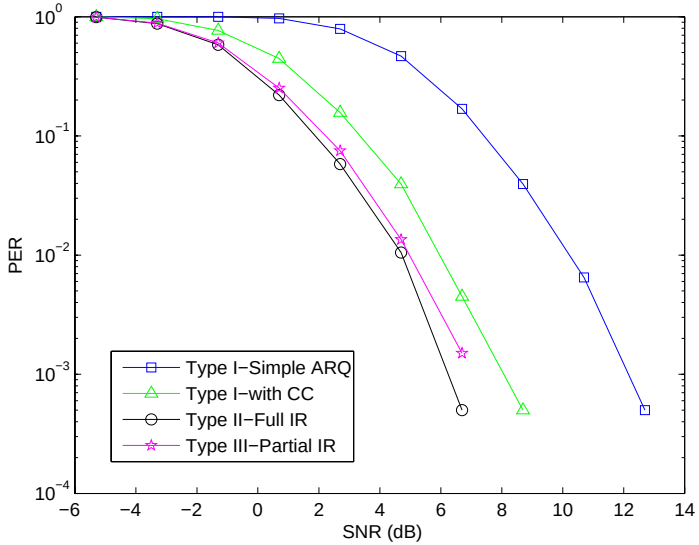
MCS	Modulation	Coding Rate
1	QPSK	1/2
2	QPSK	3/4
3	16 QAM	1/2
4	16 QAM	3/4
5	64 QAM	1/2
6	64 QAM	3/4

PER Performance of H-ARQ Schemes

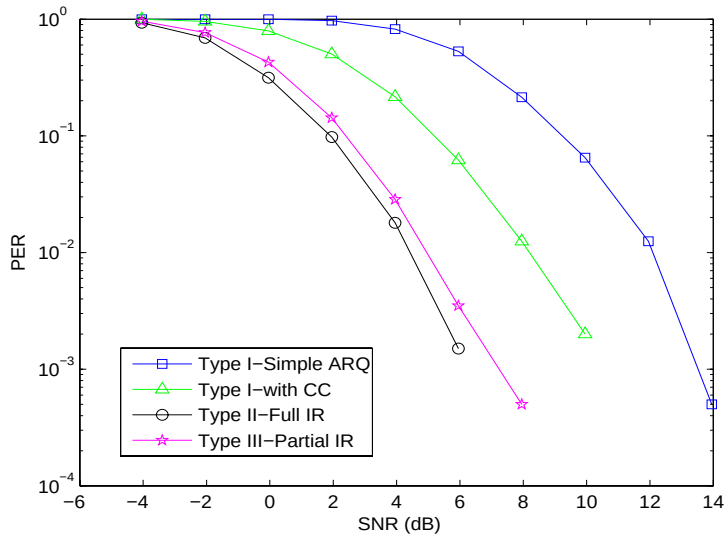
PER

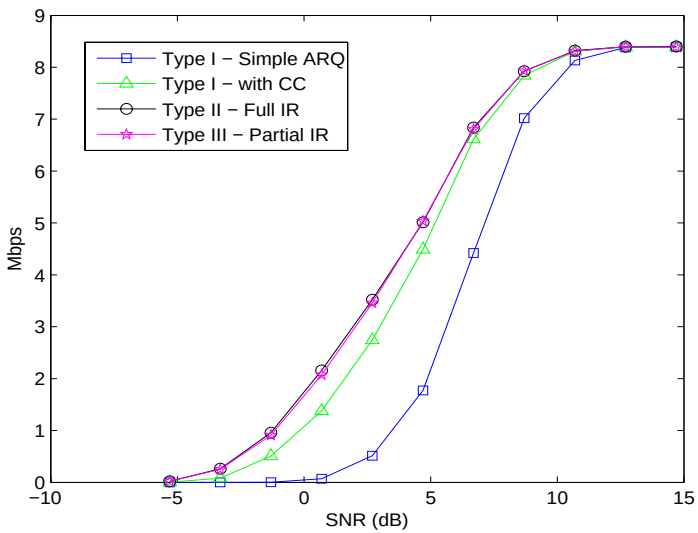
Throughput

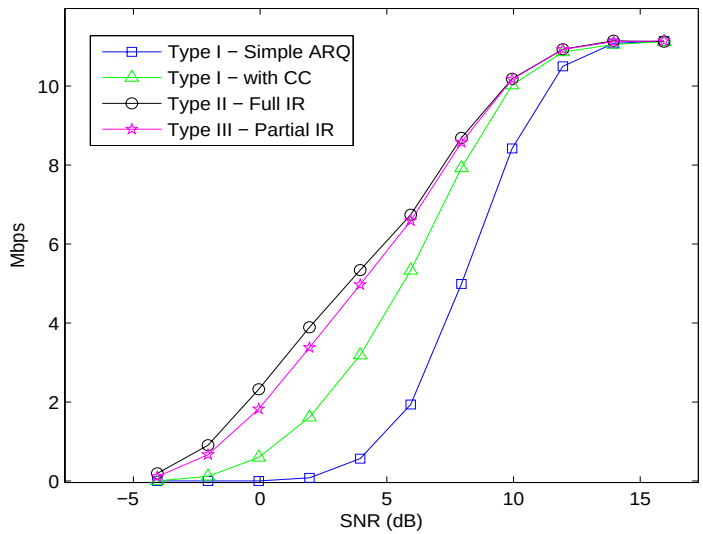
Mode 1



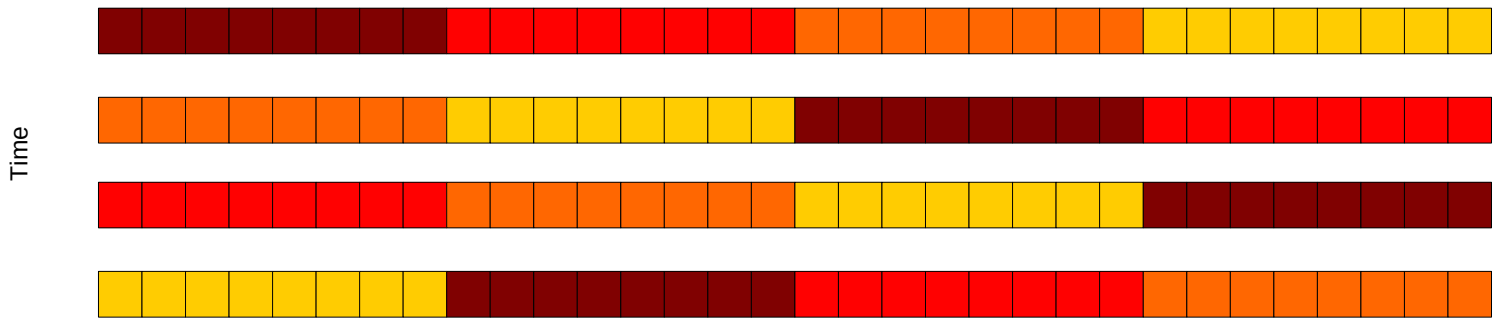
Mode 4







Diversity Technique I : Subcarrier Rearrangement



- In frequency selective channel, each OFDM subcarrier suffers different distortion and thus different received signal quality
- Assign coded bits to different subcarriers in retransmissions
- Shift the coded bits by suitable step – larger than channel coherent bandwidth
- Generates frequency diversity between retransmissions

T_n Sub 1 - - -

1

2

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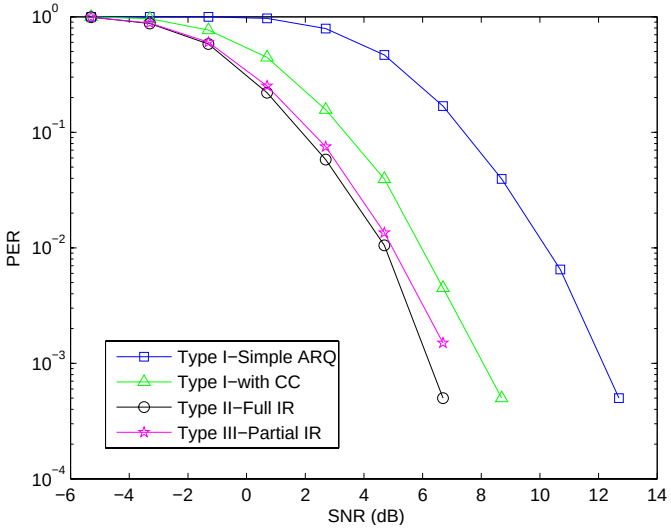
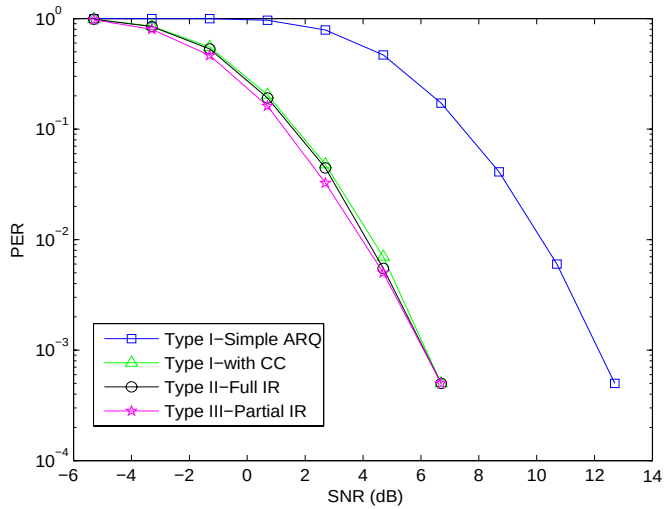
PER Performance of H-ARQ Schemes with sub-carrier mapping– Mode 1

w/o subcarrier mapping

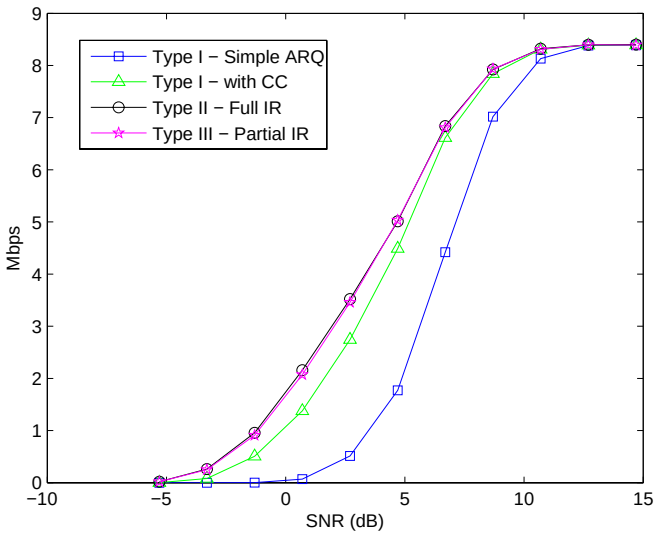
with subcarrier mapping

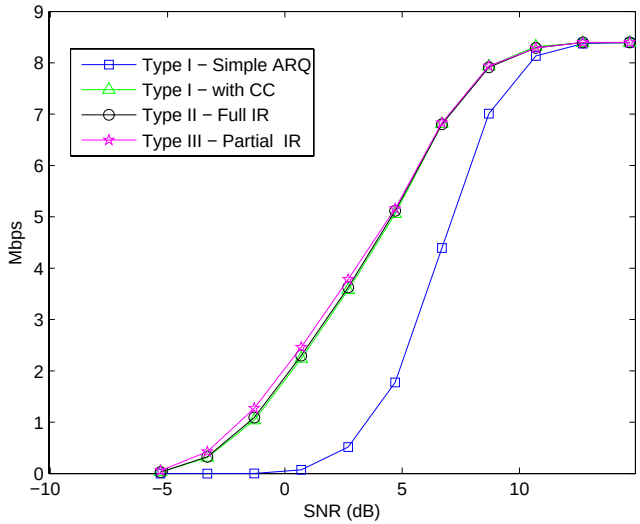
PER





Throughput

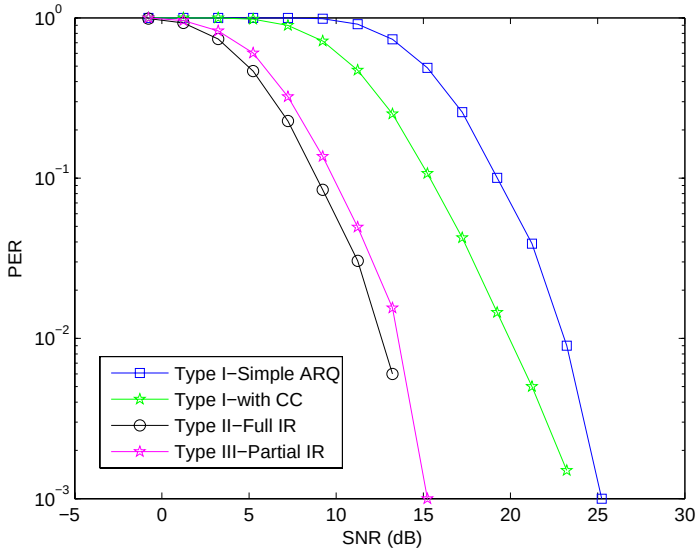




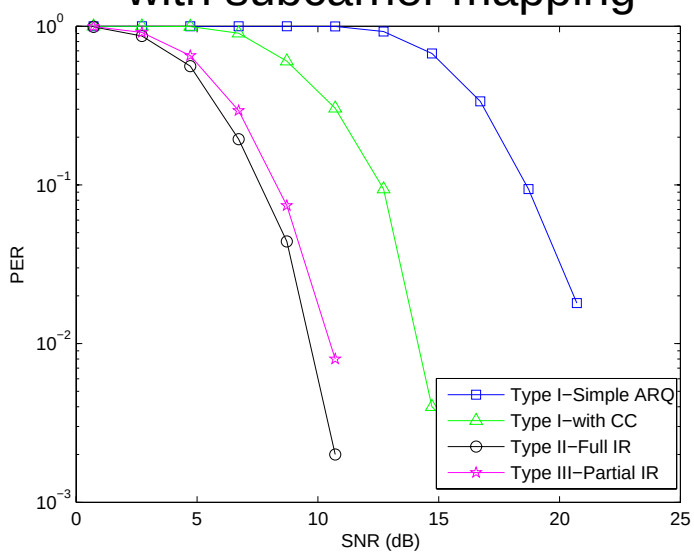
PER Performance of H-ARQ Schemes with sub-carrier mapping– Mode 6

PER

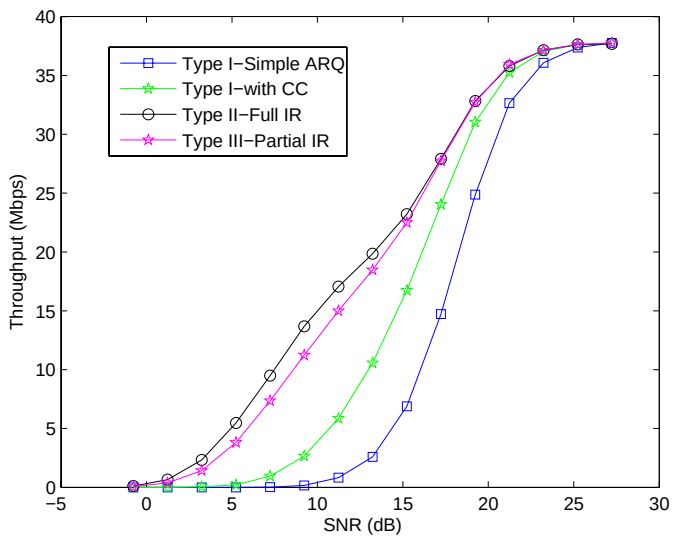
w/o subcarrier mapping

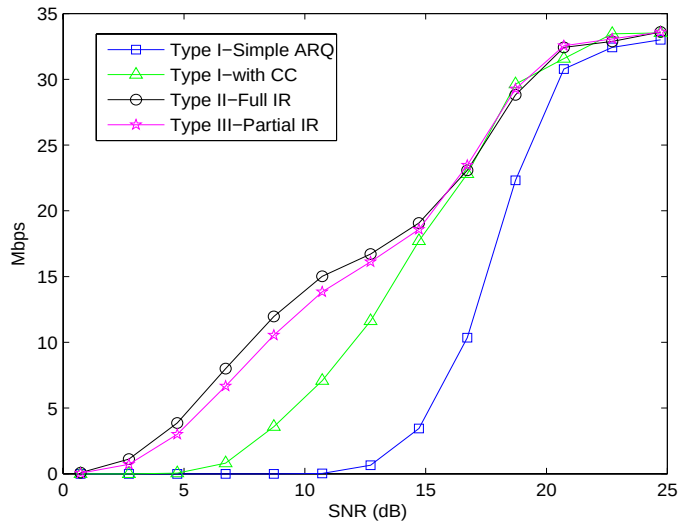


with subcarrier mapping



Throughput



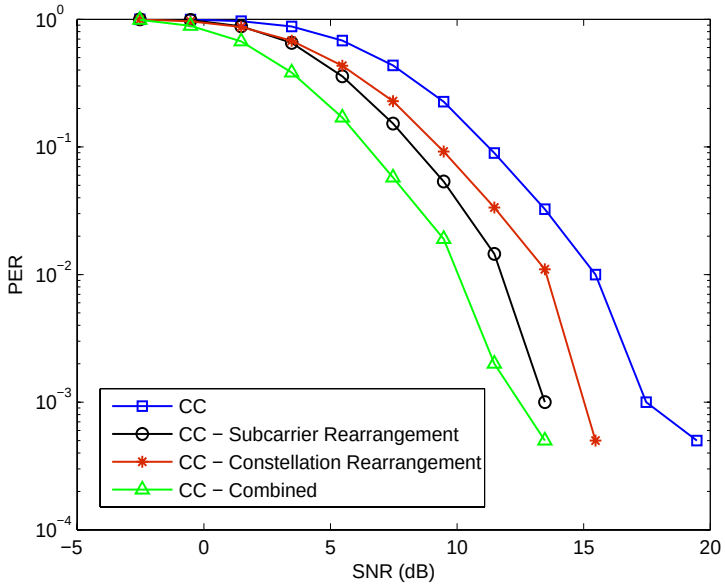


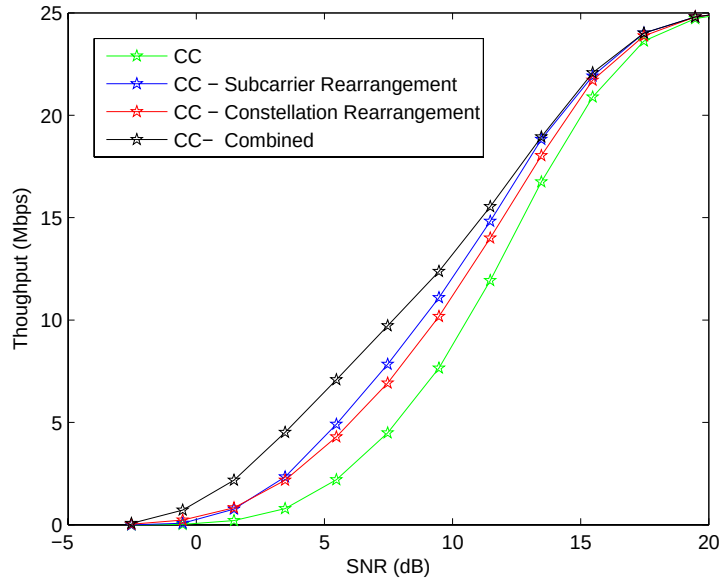
Diversity Technique II :Constellation Rearrangement

Constellation version parameter b	Output bit sequence	Operation
0	$I_1Q_1I_2Q_2$	None
1	$I_2Q_2I_1Q_1$	Swapping MSBs with LSBs
2	$I_1Q_1I_2Q_2$	Inversion of LSBs' logical values
3	$I_2Q_2I_1Q_1$	Both Swapping and inversion

- Different reliabilities exist for four bits which form a 16 QAM symbol
- Average reliabilities through retransmission by different constellation mappings
- Simple operations to rearrange the output bit sequence
- Constellation rearrangement does not require additional User Equipment (UE) buffer

PER & Throughput Performance for different diversity techniques for Chase Combining (MCS4)





- Sub-carriers rearrangement can be coupled with Constellation rearrangement to achieve further improvement

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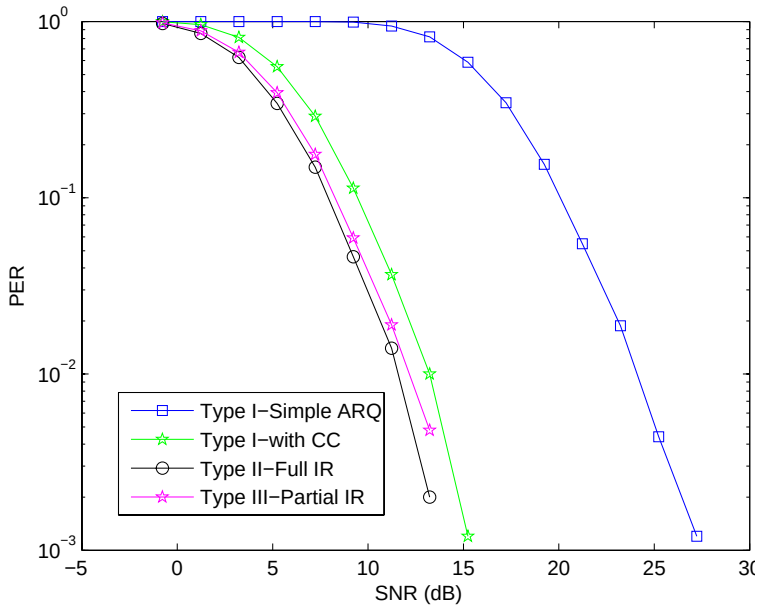
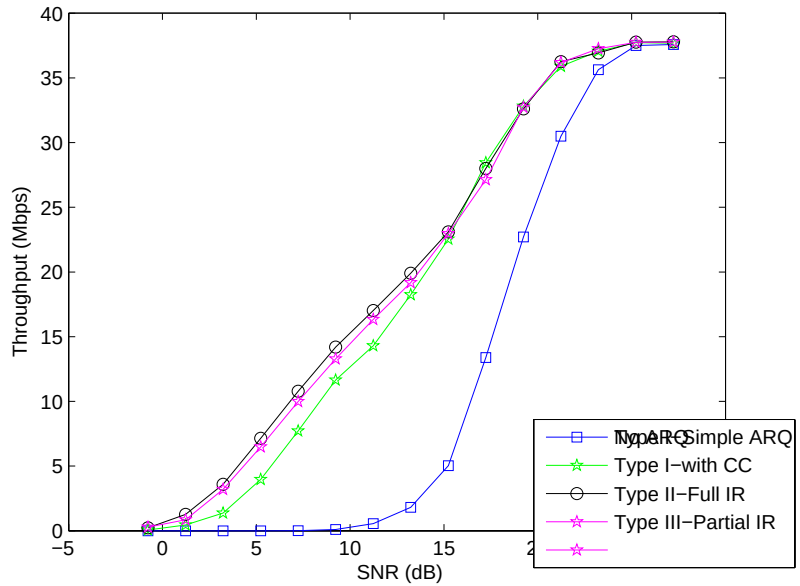
PER & Throughput performance for MCS6 for enhanced Hybrid ARQ schemes (with combined diversity techniques)





- For highest MCS scheme, Full IR and Partial IR still perform better due to significant decoding gain but only up a margin of approx. 2 dB

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Conclusion on Hybrid ARQ Performance

- Different subcarriers and constellation mapping in retransmission(s) achieve diversity effects
- Without diversity strategies, Full and Partial IR achieve best throughput performance
- Chase Combining gets most benefit from diversity strategies, Partial IR gets less than CC and followed by Full IR
- For highest MCS scheme, Full IR and Partial IR still perform better due to significant decoding gain but only up a margin of approx. 2 dB

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Thank you

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